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DETERMINATION OF WATER INFLUX IN RESERVOIR IN NIGER DELTA

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ABSTRACT
Reservoirs produced by a mechanism termed water drive. Often this is called natural water drive to distinguish it from artificial water drive that involves the injection of water into the formation. Hydrocarbon production from the reservoir and the subsequent pressure drop prompt a response from the aquifer to offset the pressure decline. This response comes in a form of water influx. This paper is to determine water influx in reservoir in Niger Delta using van everdingen-hurst unsteady-state model . In doing this, the theoretical aspect of these models were looked at and validation of production data was carried out. .then the application of the model was also considered by using production data . The results show that estimated value of water influx was 63057231.92bbl for one year and 2250770727 bbl at the end of seven years. The results were also compared with the company values.It is clear from the graph there is little disparity between these models. From the t-test carried out we concluded that there is significant difference between the two models. For exact solution Van Everdingen-Hurst is suitable. However, for easy and approximate solution, Company(Hurst-VaneEverdinge-Odeh) Models is preferred.

KEYWORDS: Estimation, water influx, reservoir, model, mechanism

INTRODUCTION
There are several models used in Petroleum industry to estimate water influx, this include the following(Tarek.H.Ahmed:Reservoir Engineering Handbook):

*Pot Aquifer
*Schilthuis' steady- state
*Hurst's Modified steady-state
*The Van Everdingnen-Hurst Unsteady-state
*The carter-Tracy Unsteady-state
*Fetkovich's Method.

In this paper, water influx in reservoir will be determined using van everdingen-hurst unsteady-state model. The values obtained will be compare with the company model This particular paper is particular seeks to empower the reservoir Engineers and those involve in reservoir management to know suitability of the model.

RESEARCH METHODOLOGY
In this section, the focus is on the design of the research, area of study and method of data collection and method of analysis.

RESEARCH DESIGN
In this work, field "X" was used as a case study and application of the model will be demonstrated .The following steps will be taken in using the models:

Step1,Determine water influx constant B

Step2, For each time period, calculate ΔP

Step3, Calculate dimensionless times t_D

Step4, For each t_D computed in step3, calculate a dimensionless cumulative water influx

Step5, Calculate W_e

Step6, Summary of the final results

AREA OF STUDY The work is focused on Van Everdingen-Hurst Model .

METHOD OF DATA COLLECTION
The data for this work was obtained from record.

METHOD OF DATA ANALYSIS
In analyzing the data collected, graph of reservoir pressure and time was drawn and determination of drive index was carried out.

DETERMINATION OF DRIVE INDEXES
Oil is produced from many reservoirs by more than one natural production mechanism .In managing such a reservoir; it is useful to make an estimate of the fraction of total production that should be attributed to each of the mechanisms that are present. Pirson has proposed the use of drive indexes to answer that question. The derivation is based on the relationship;

(oil expansion) +(free gas expansion) + (net water influx) + (net injection) = (Production)

If this equation is written in mathematical form,then divided by the production term on the right side of the equation relationship is obtained in the form (L.F.Koederitz,A.H.Harvey and M.Honarpour ,1989):

$$DDI+SDI+WDI+IDI=0 \text{ -------------1}$$

Where the solution gas drive index (also called the depletion drive index or DDI) may be expressed by the term

$$\frac{N[B_O + (R_{si} - R_s)B_g] - NB_{oi}}{N_p B_O + G_p B_g - N_p R_s B_g} - - - -2$$

The gas cap expansion drive index(also called the segregation drive index SDI) may be written:

$$\frac{GB_g - GB_{GI}}{N_p B_O + G_p B_g - N_P R_S B_g} \text{------------3}$$

The water drive index(or WDI):

$$\frac{W_e - W_p B_W}{N_p B_O + G_p B_g - N_P R_s B_g} \text{---------4}$$

The injection drive index (IDI) is:

$$\frac{W_I B_W + G_I B_g}{N_p B_O + G_p B_g - N_P R_S B_g} \text{----------5}$$

RESULTS AND ANALYSIS
APPLICATION AND RESULTS OF VAN EVERDINGEN-HURST MODEL
The application of this model will be illustrated using the information in Tables 1.0 and Table2.0 .Table1.0 gives information on estimated properties of the aquifer.Table2.0 gives information on Pressure History at the

Reservoir/Aquifer Boundary (Dake,L.P.,1978).As reservoir fluids are produced, reservoir pressure declines.Fig1.0 illustrate reservoir pressure declination.

Table1.0 The estimated properties of the Aquifer.

Ø	$\mu(C_p)$	Θ	K(md)	$C_t(psia^{-1})$	h(ft)	r_r(ft)
0.23	0.1728	160	2180	$7x10^{-6}$	212	6561.6797

Table2.0:Pressure History at the Reservoir/Aquifer Boundary.

Pressure(Psia)	3452.30	3328.8	3263.91	3142.93	2999.57	2870.8	2758.08	2714.24
Time(days)	0	365	728	1090	1455	1820	2185	2551
W_e (MMbbl)	0	1.52	4.18	8.13	13.0	18.9	25.75	32.52

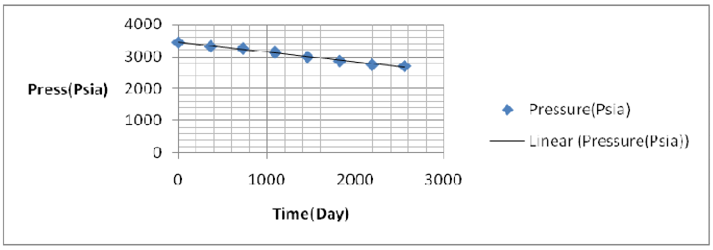

Fig1.0 Reservoir pressure decline

DETERMINATION OF DRIVE MECHANISMS AND DRIVE INDICES

The drive indices are calculated as follow.

For solution gas drive index (also called the depletion drive index or DDI) may be expressed by the term:

$$\frac{N[B_O + (R_{si} - R_s)B_g] - NB_{oi}}{N_pB_O + G_pB_g - N_PR_sB_g}$$

$$\frac{2.63x10^8[1.7165 + (1378.99 - 1266.31)8.19x10^{-4}] - 2.63x10^8x1.7718}{5.16x10^7x1.7165 + 7.71x10^{10}x8.19x10^{-4} - 5.16x10^7x1266.31x8.1910^{-4}}$$

$$=\frac{9.73x10^6}{9.8210^7}=0.0991$$

For gas cap expansion drive index(also called the segregation drive index SDI) may be written

$$\frac{GB_g - GB_{GI}}{N_pB_O + G_pB_g - N_PR_sB_g}$$

$$\frac{1.18x10^{12}x8.19x10^{-4} \quad 1.18x10^{12}x7.6x10^{-4}}{5.16x10^7x1.7165 + 7.71x10^{10}x8.19x10^{-4} - 5.16x10^7x1266.31x8.1910^{-4}}$$

$$\frac{6.30x10^7}{9.82x10^7}= 0.642$$

For water drive index(or WDI):

$$\frac{W_e - W_p B_w}{N_p B_O + G_p B_g - N_P R_s B_g}$$

$$\frac{3.25x10^7 - 8.80x10^5 x1.03}{5.16x10^7 x1.7165 + 7.71x10^{10} x8.19x10^{-4} - 5.16x10^7 x1266.31x8.1910^{-4}}$$

$$\frac{3.16x10^7}{9.82x10^7} = 0.322$$

For injection drive index (IDI) is:

$$\frac{W_t B_w + G_I B_g}{N_p B_O + G_p B_g - N_P R_s B_g}$$

$$\frac{0x1.03+0x8.19x10^{-4}}{5.16x10^7 x1.7165+7.71x10^{10} x8.19x10^{-4} - 5.16x10^7 x1266.31x8.1910^{-4}}=0$$

Therefore from equation 3.0

$$0.0991 + 0.642 + 0.322 + 0 = 1.06$$

The calculation of drive indices show that production of this reservoir involve combination of drive mechanisms and also show that there was water influx.

Using the information in Tables 1.0 and 2.0.

Step1, Determine water influx constant B use equation 10.0

$$B = 1.119 \emptyset C_t h r_r^2 \left(\frac{\theta}{360}\right) \text{-----------10.0}$$

$$= 1.119(0.23)(7x10^{-6})(212)(6561.6797)^2\left(\frac{160}{360}\right)$$

=7308.687RB/Psi

Step2, For each time period, calculate ΔP using Eq.11.0

$$\Delta P_n = \frac{1}{2}(P_{n-2} - P_n) \text{------------11.0}$$

For n=1

$$\Delta P_1 = \frac{1}{2}(3452.3 - 3328.8) = 61.75$$

For n=7

$$\Delta P_7 = \frac{1}{2}(2870.8 - 2714.24) = 78.28$$

Step3, Calculate dimensionless times t_D using Eq12.0.

$t_D=\frac{0.00633Kt}{\varnothing\mu\, C_t r_r^{\,2}}$----------12.0

$$t_D = \frac{0.00633(2180)t}{0.23(0.1728)(7x10^{-6})(6561.67979)^2}$$

= 1.1466t

For example at t = 365days

$$t_D= (1.1466)(365) = 418.51$$

Step4, For each t_D computed in step3, calculate a dimensionless cumulative water influx. Because we are assuming an infinite-acting aquifer,we can use equations 13.0 since t_D is greater than 0.01 and less than 200(John,L. and Robert.A.W,1996) . The value of t_D determines which equation to use. For example at t =365 days (n=1),t_D=418.51 .Since t_D >200,

so we use Eq.13.0

$Q_{PD(t_D)} = \frac{-4.29881+2.02566\,t_D}{In(t_D)}$-------13.0

$$Q_{PD}(t_D) = \frac{-4.29881+2.02566(365)}{In365} = 139.72$$

Table3.0 summarizes the intermediate results from step2 through 4

Table3.0 Summary of intermediate results using Van Everdingen-Hurst Model

N	Time(days)	t_D	P (Psia)	ΔP_n (Psi)	$Q_{PD}(t_{Dn})$
0	0	0	3452.30	0	0
1	365	418.51	3328.8	61.75	139.72
2	728	834.72	3263.91	94.20	250.71
3	1090	1249.79	3142.93	92.94	354.43
4	1455	1668.33	2999.57	132.17	454.9
5	1820	2086.81	2870.8	136.65	552.49
6	2185	2505.32	2758.08	120.75	647.91
7	2551	2924.98	2697.49	78.28	741.85

Step5, Calculate W_e using Eq.14.0

$W_e\,(t_{Dn}) = B\sum_{i=1}^{n} \Delta P_i Q_{PD}(t_n-t_{i-1})_D$

For example, at n=1

$W_e\,(t_{D1}) = B\sum_{i=1}^{1} \Delta P_i Q_{PD}(t_1-t_{i-1})_D$

$=B[\Delta P_1 Q_{PD}(t_1-t_0)_D = B[\Delta P_1\, Q_{PD}(t_{D1})=7308.687(61.75x6.3269)$

=63057231.92bbl

Similarly, for n= 6$W_e(t_{D6}) = B\sum_{i=1}^{6} \Delta P_i Q_{PD}(t_6-t_{i-1})_D$-----------15.0$= B[\Delta P_1 Q_{PD}(t_6 - t_0)_D + \Delta P_2 Q_{PD}(t_5)_D + \Delta P_3 Q_{PD}(t_{D4})$

$+ \Delta P_4 Q_{PD}(t_{D3}) + \Delta P_5 Q_{PD}(t_{D2}) + \Delta P_6 Q_{PD}(t_{D1})]$

=7308.687[(61.75)(647.91)+(94.195)(552.49)+(92.935)(454.9)+(132.17)(354.43)+(136.65)(250.71)+(120.745)(139.72)]

=1697860109bbl

Table4.0 summarizes final results using Van Everdingen-Hurst Model.

Table4.0 Summary of final results using Van Everdingen-Hurst Model

N	Time(days)	P (Psia)	W_e(bbl)
0	0	3452.30	0
1	365	3328.8	63057231.92
2	728	3263.91	209342476.9
3	1090	3142.93	427474222.2
4	1455	2999.57	754586564.6
5	1820	2870.8	1185013265
6	2185	2758.08	1697860109
7	2551	2697.49	2250770727

Table5.0 Van Everdingen Hurst and (Everdingen&Odeh(MMBBL))Company Models

N	VanEverdingenHurst(BBL)	Everdingen&Odeh(MMBBL)
0	0	0
1	63057231.92	1.52
2	209342476.9	4.18
3	427474222.2	8.13
4	754586564.6	13
5	1185013265	18.9
6	1697860109	25.75
7	2250770727	32.52

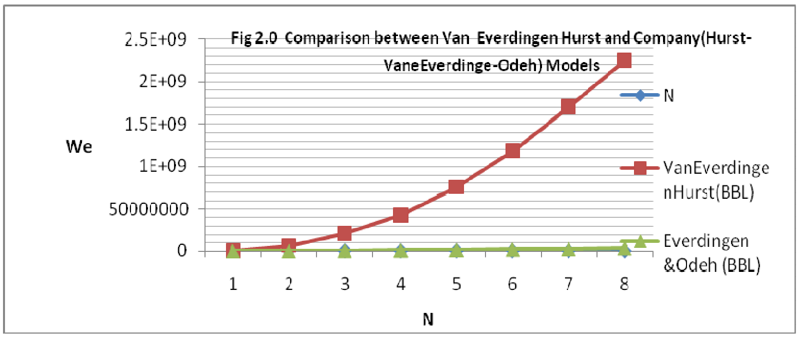

Fig2.0 shows comparison between Van Everdingen Hurst and Company Models

DISCUSSION

.In analyzing the data used for the application of this models, reservoir pressure was plotted against time as shown in fig1.0. Fig1.0, illustrates the decline in the boundary pressure as a function of time for a radial reservoir –aquifer system. If the boundary pressure is reduced, pressure drop will be imposed across the aquifer. Water will continue to expand and the new reduced pressure will continue to move outward into the aquifer. Since these pressure waves are assumed to occur at different times, they are entirely independent of each other. Thus, water expansion will continue to take place as a result of the first pressure drop, even through additional water influx is also taking place as a result of one or more later pressure drops. This is essentially an application of the principle of superposition (Craft,B.,Hawkins.M and Terry.R ,1991). In order to determine the total water influx into a reservoir at any given time, it is necessary to determine the water influx as a result of each successive pressure drop that has been imposed on the reservoir and aquifer. In calculating cumulative water influx it is necessary to calculate the total water influx from the beginning. This is required because of the different times during which the various pressure drops have been effective[1] . Van Everdingen-Hurst methodology provides the exact solution to the radial diffusivity equation and therefore considered the correct technique.

The final results for the model is shown in table4.0 above. The difference between the Company(Hurst-VaneEverdingen-Odeh) technique and the Van Everdingen –Hurst technique is shown in table5.0.Graphically, fig2.0 compare the model with the company model(Hurst-van Everdingen-Odeh) . It can be seen that there is little disparity (Andy,I.J., 2000) between the two models

CONCLUSION

In concluding this paper it is once again necessary to highlight what the original aim of the paper was in the first place. The aim of the work is to determine water influx using Van Everdingen-Hurst model. Objective of this is to determine suitability of the model in estimating water influx in Niger Delta .This will assist the reservoir Engineers and production managers in during reservoir management. This aim to a large extent could be said to have been achieved.

RECOMMENDATION

What has been presented in this paper is perhaps a first attempt at providing the reservoir Engineers and production managers a means of determining which of the model to use when calculating water influx and as can not be said to be conclusive. Consequently, the following recommendation for further research work have been made.

1 The model can be compare with Carter-Tracy method
2 I also recommend that the model should be compared with fetkovich model.

NOMENCLATURE

C_t = Total aquifer compressibility. Psi^{-1}
C_f = Aquifer rock compressibility Psi^{-1}
C_w = Aquifer water compressibility Psi^{-1}
h =Net formation thickness. ft
e_w = water influx rate from aquifer, bbl/day
P_{aq} = Aquifer pressure, psia
P_D = Dimensionless pressure
P_r = Pressure at aquifer/reservoir interface. Psia
ΔP = Dimensionless difference between initial aquifer pressure and pressure at original reservoir/aquifer boundary, Psia.
r_r = Radius to aquifer/reservoir interface
r_a= Radius of the aquifer
Φ= Porosity of the aquifer
W_e = Cumulative water influx. RB
Z_D = Dimensionless vertical distance
K_v= vertical permeability
K_h = horizontal permeability

W_{ei} = Initial encroachment volume in a aquifer, RB
W_i = Initial volume of water in a aquifer,RB

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